From Order to Space in One Year... The MECA Electrometer Experience

M. G. Buehler, Li-Jen Cheng, and O. Orient
Microdevices Laboratory
Jet Propulsion Laboratory
California Institute of Technology

R. Gompf, J. Bayliss, and J. Rauwerdink
Material Science Laboratory
Kennedy Space Center
NASA

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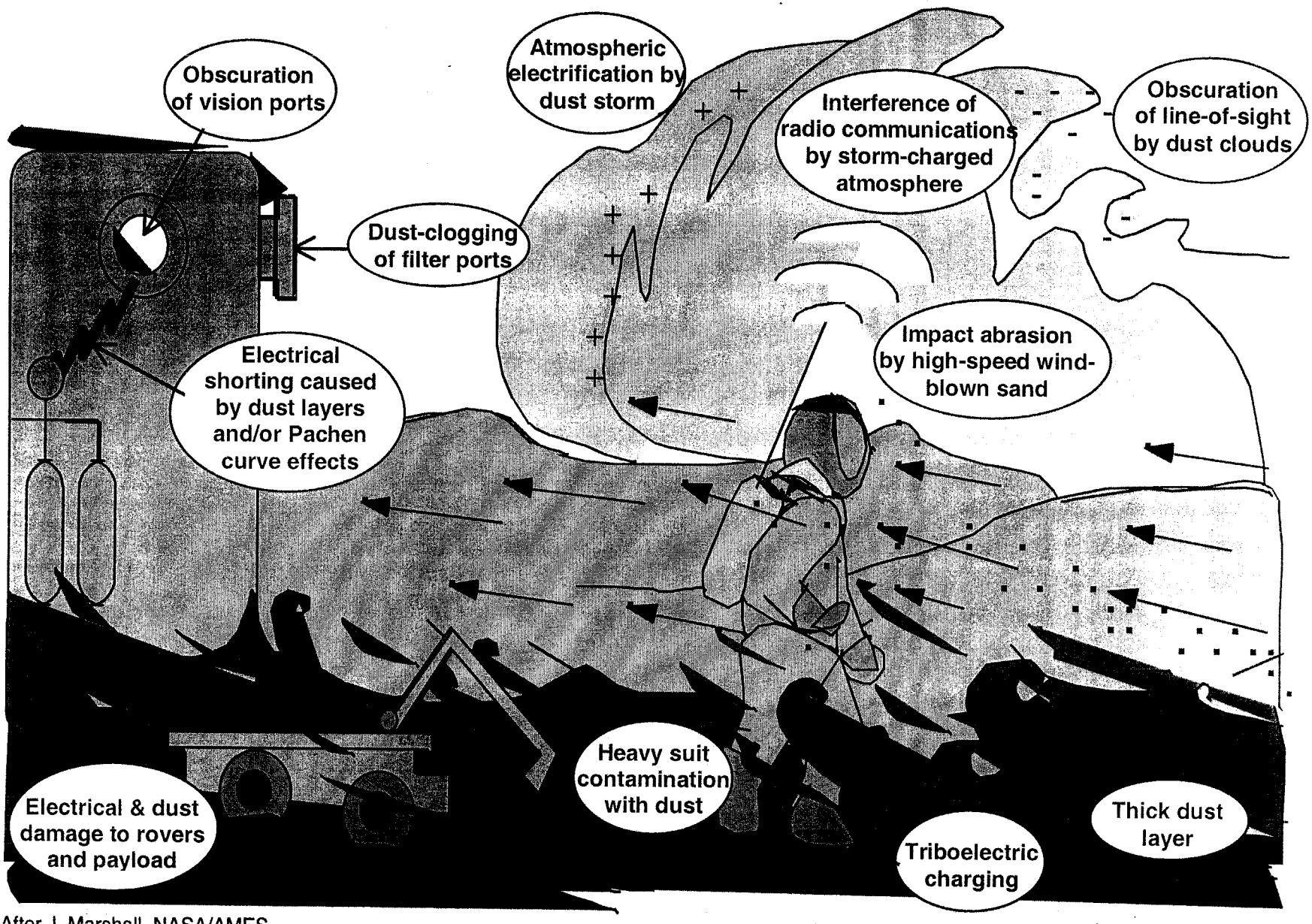
MARS ELECTROSTATIC ENVIRONMENT



After J. Marshall, NASA/AMES

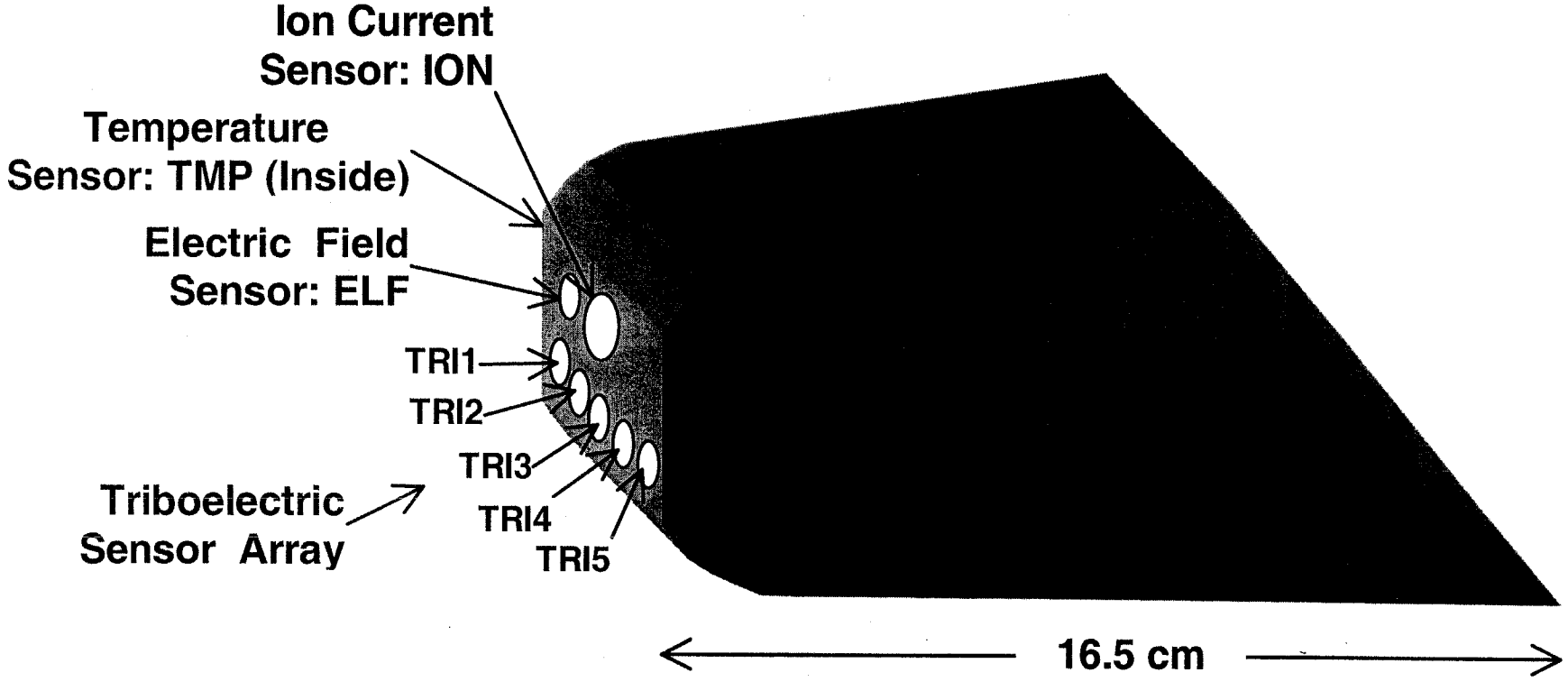
MECA ELECTROMETER OBJECTIVES AND APPROACH

OBJECTIVE: **To determine the nature of the electrostatic properties of the Martian atmosphere and regolith**

- by measuring the pick-up of triboelectrically-induced charge during the operation of the robotic arm while moving through the Martian soil using a Triboelectric Sensor,

- by measuring the strength of the electric field above the Martian soil by using the arm to raise and lower electrometer above the soil by using an Electric-Field Sensor, and

- by measuring the atmosphere ion currents especially those generated by the wind while the arm is fully extended vertically by using an Ion Chamber.



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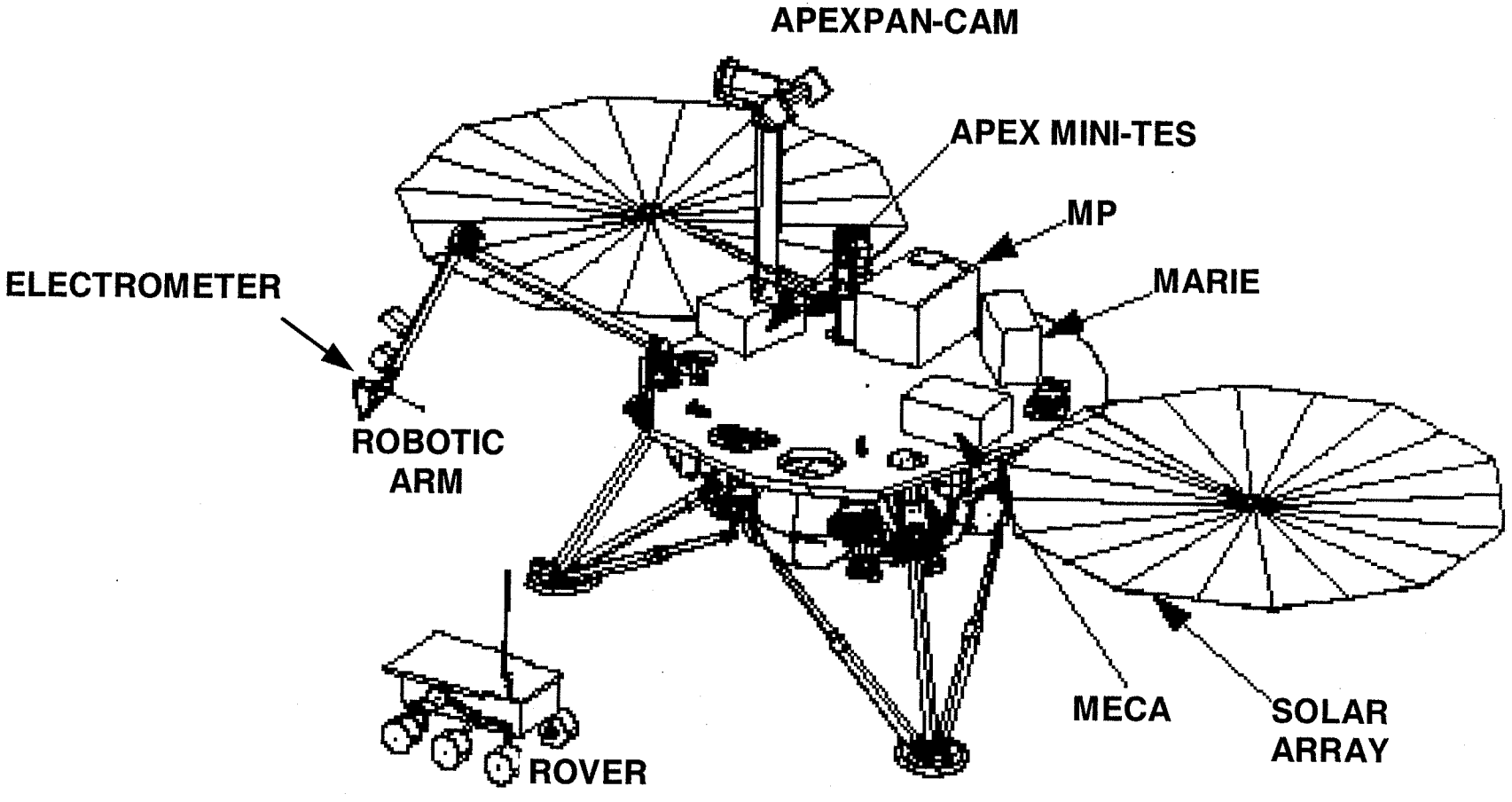
Mars 2001 Lander



MECA Electrometer Mounted in the Heel of the Robotic Arm Scoop

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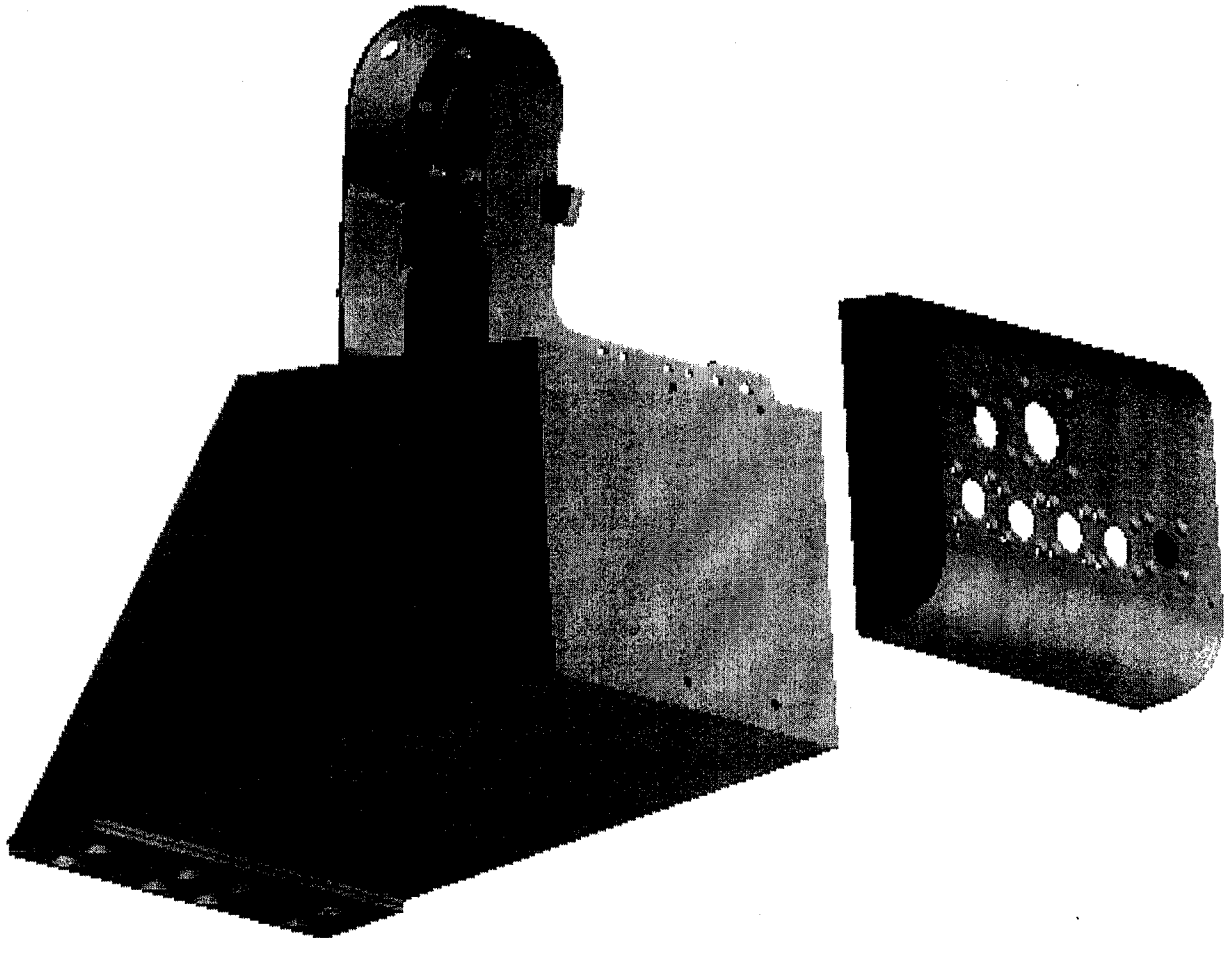
MECA Electrometer Mounted in the Heel of the Robot Arm Scoop



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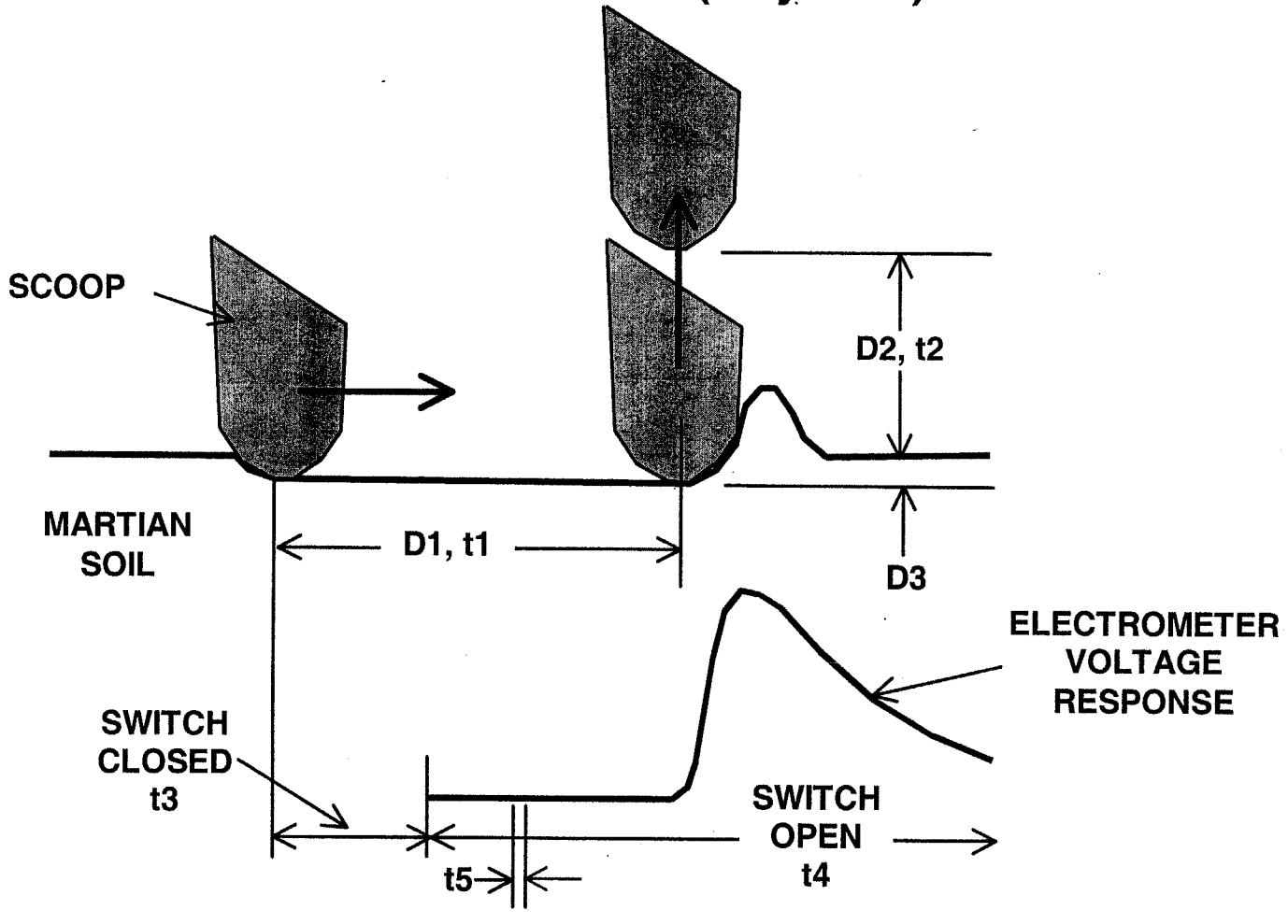
OPERATION (Physical)



Recommended operating parameters: D1 = 10 cm, D2 = 1 cm, D3 = 0.5 to 1 cm, t1 = 10 s, t2 = 0.5 s, t3 = 1 s, t4 = 19 s, t5 = 0.1 s (t5 is the time interval between acquiring data).

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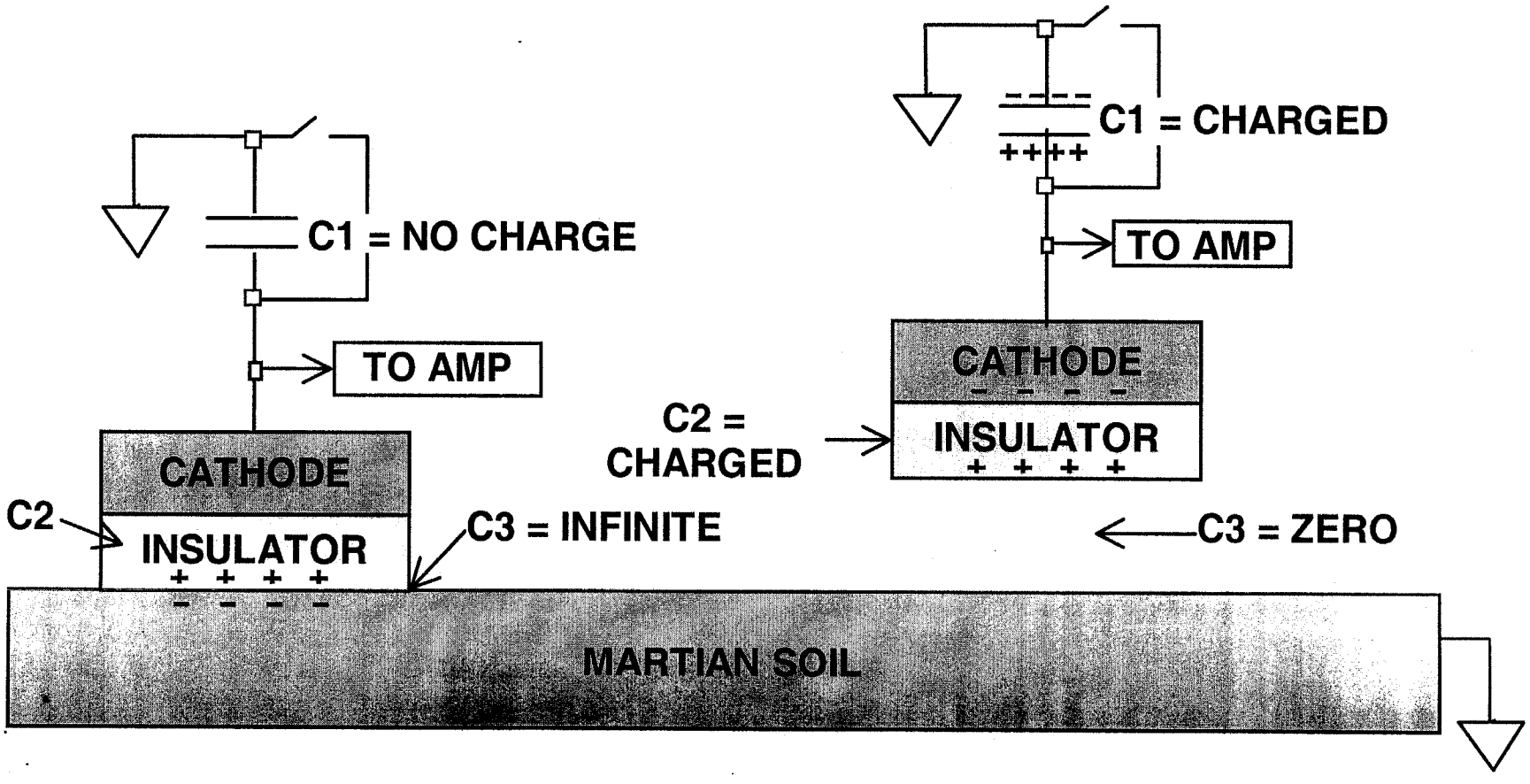
OPERATION (Electrical)



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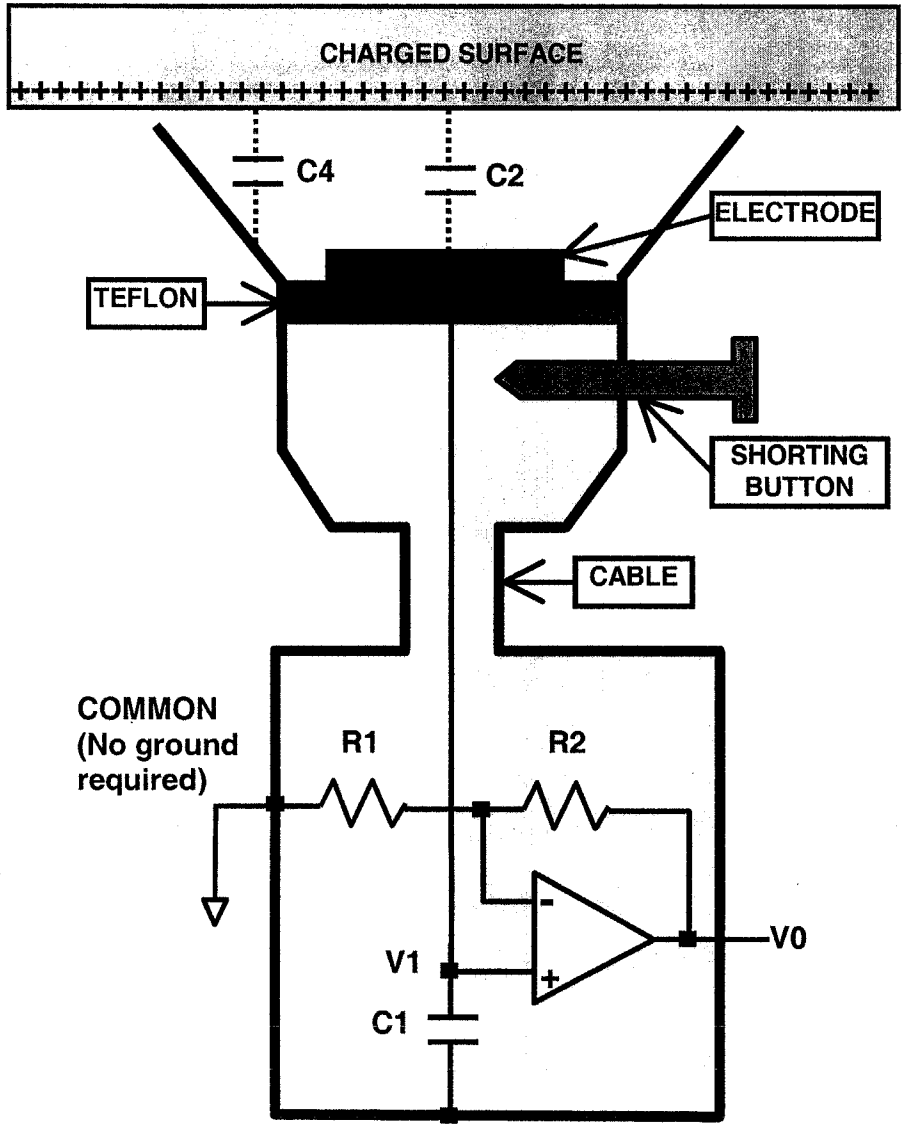
KEITHLEY ELECTROMETER (circa 1960)



- Three-node circuit consists of C1, C2, and C3.
- Shorting button used to remove charge from C1 and thus zero the instrument.
- Electrometer is a high-input impedance follower Op Amp with gain.
- Since C1 >> C2 and C1 >> C3, the potential at the Op Amp is in the millivolt range and thus protected from the high potentials that appear across C2 and C3.

Ref.: *Electrometer Measurements*, Keithley Instruments (Cleveland, Ohio, 1972).

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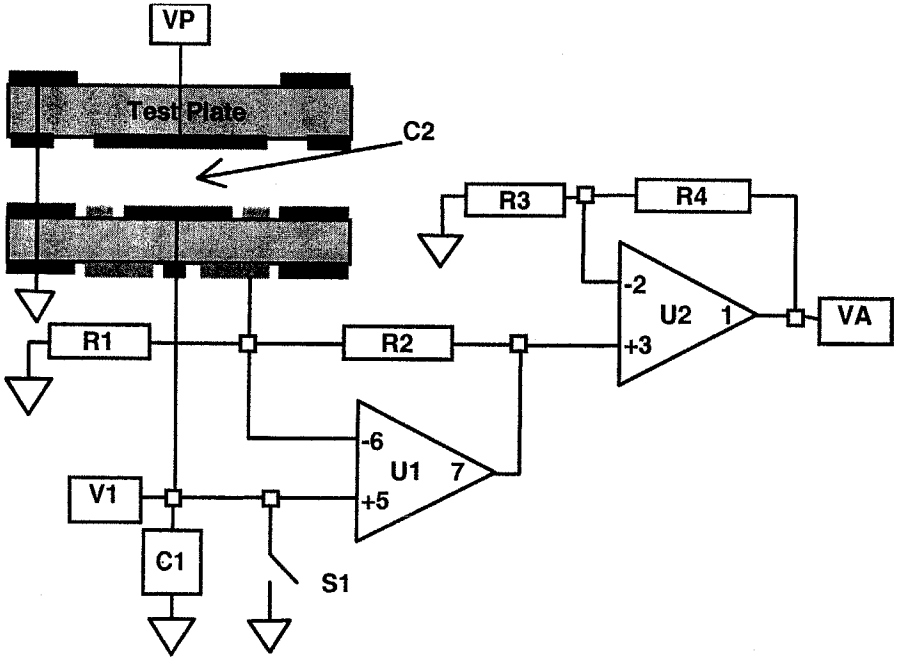
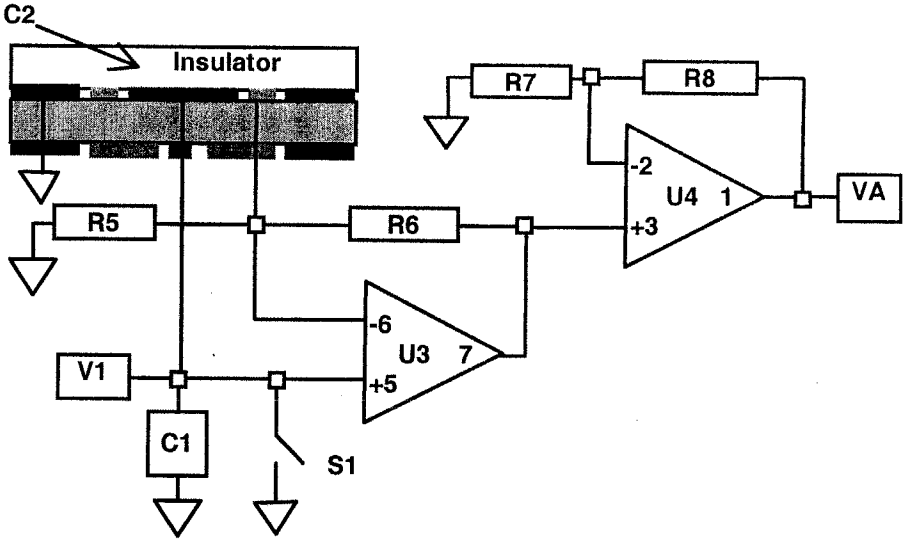
ELECTRIC FIELD AND TRIBOELECTRIC CIRCUITRY



(a) Electric field sensor with test plate.



(b) Triboelectric sensor with insulator.

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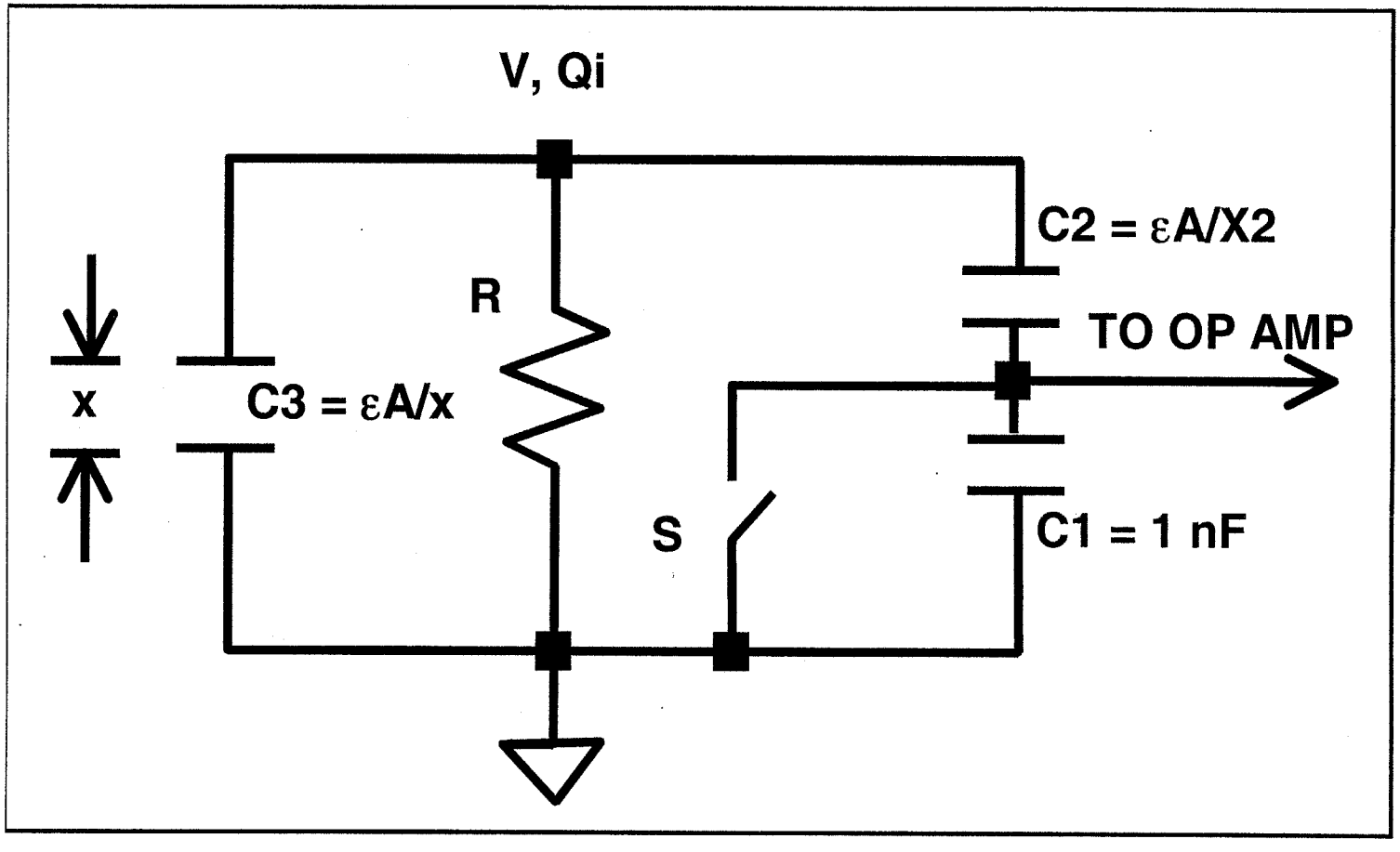
TRIBOELECTRIC SENSOR MODEL



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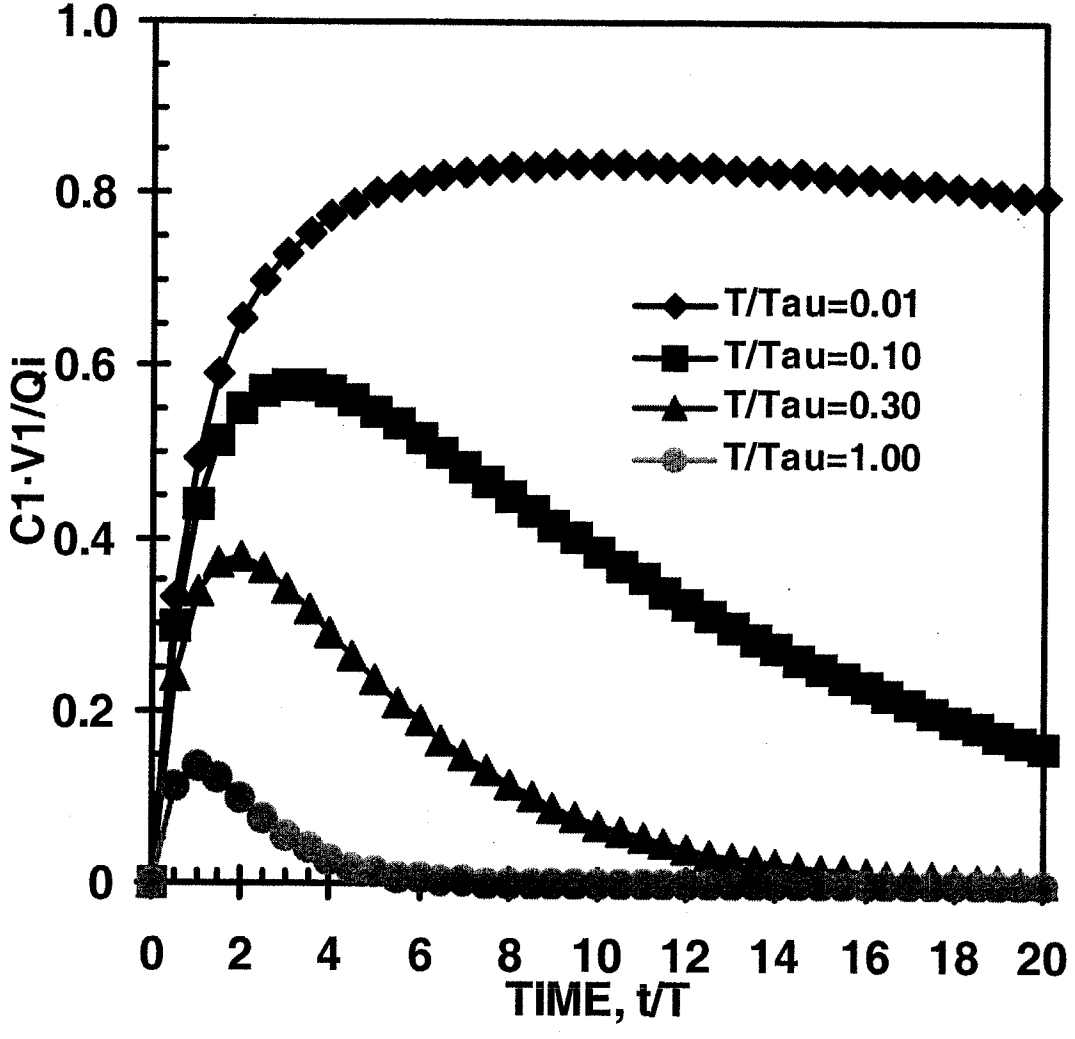
TRIBOELECTRIC RESPONSE CURVES



After rubbing the surface, the electrometer lifts off from surface with a constant velocity, v, and charge Qi. The time from liftoff is t, Tau = R·C0, and T = εA/(v·C0) where C0 = C1·C2/(C1+C2) and C3 = εA/X.

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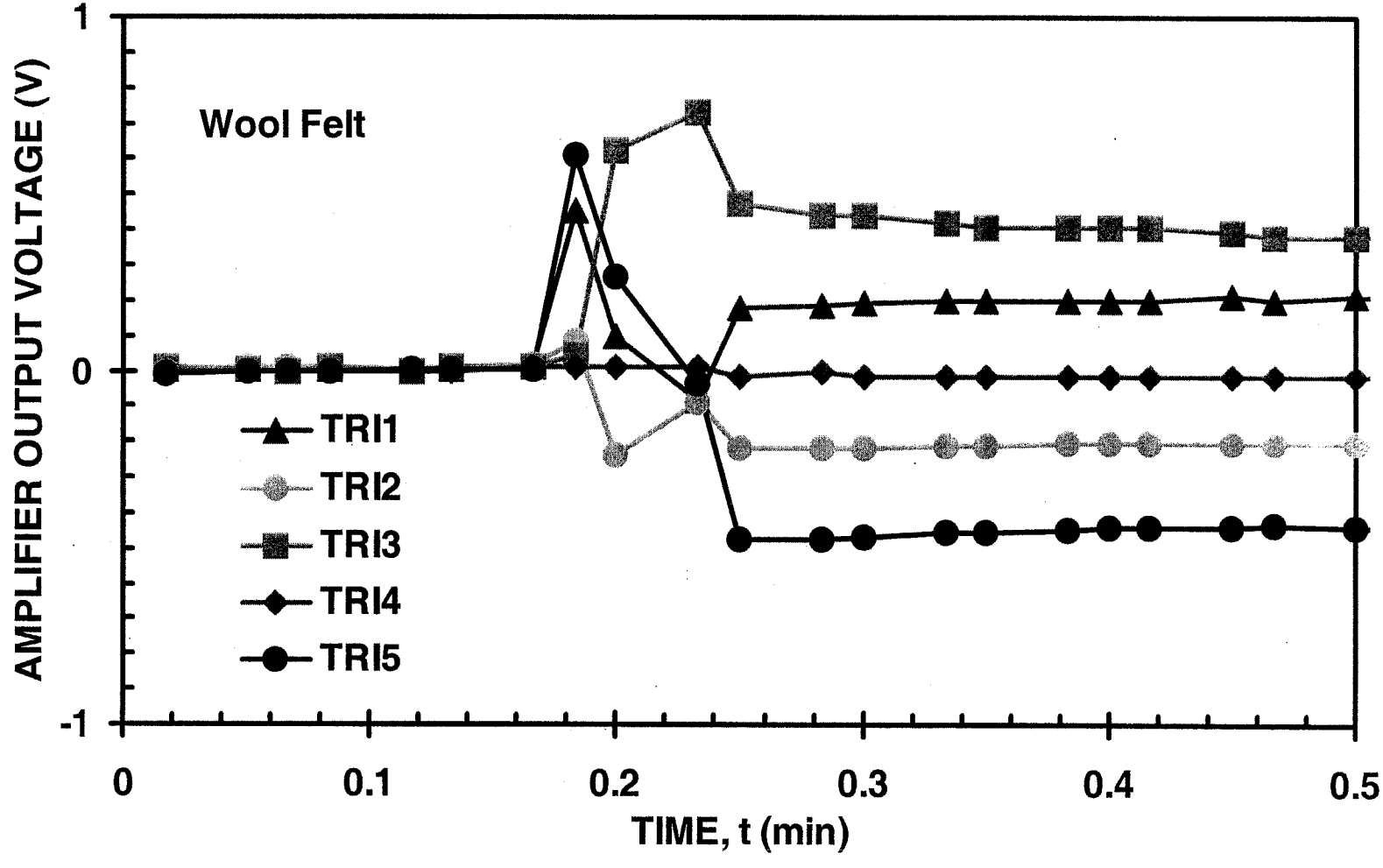
Triboelectric Sensor Response: Hand Rubbing



TRI1 is ABS, TRI2 is polycarbonate, TRI3 is linen filled phenolic, TRI4 is Rulon-J, and TRI5 is Teflon which were rubbed with wool felt.

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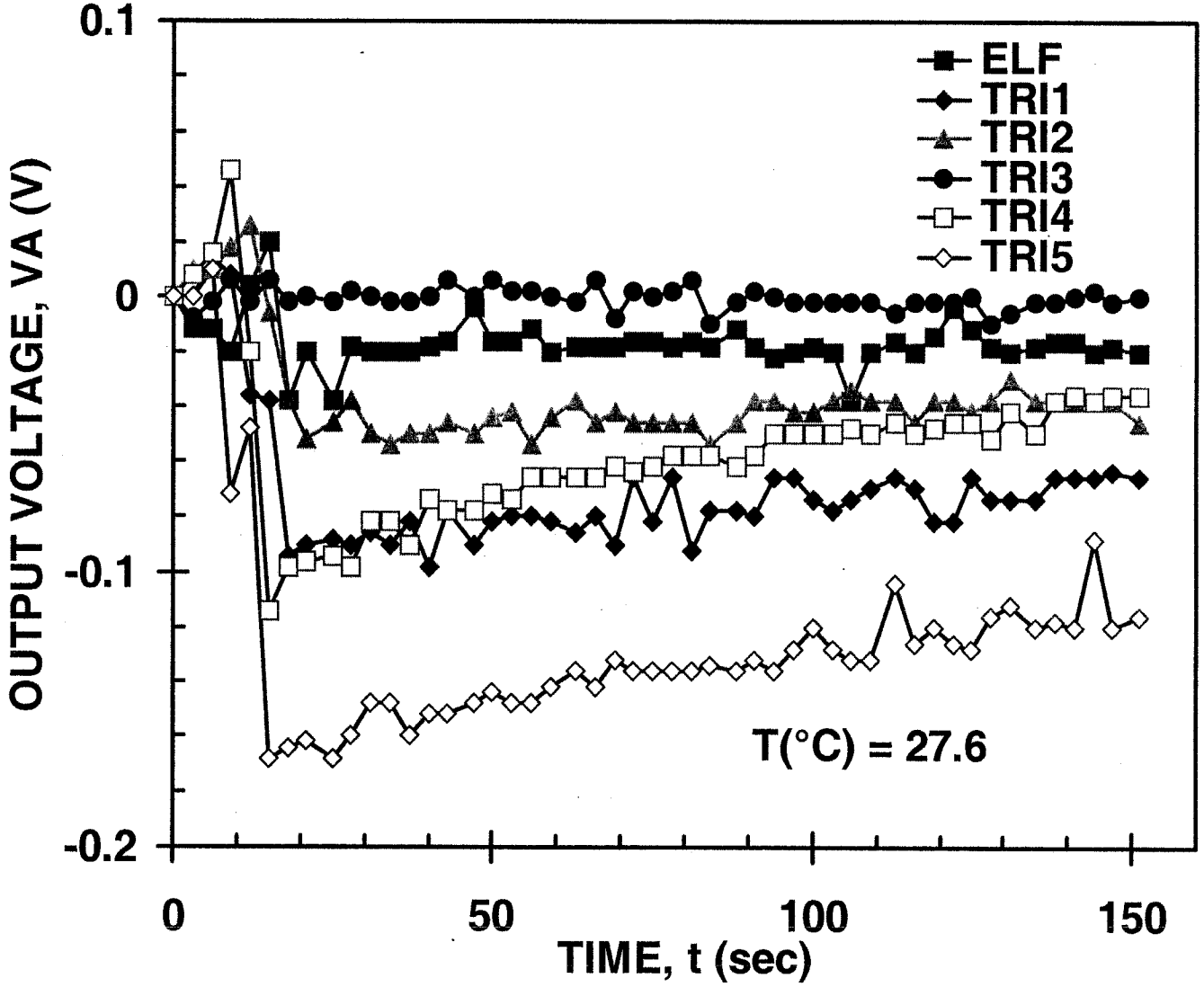
Triboelectric Sensor Response: Rubbing Apparatus w/ Wool Felt



TRI1 is ABS, TRI2 is polycarbonate, TRI3 is velostat, TRI4 is Rulon-J, and TRI5 is Teflon which were rubbed with wool felt.

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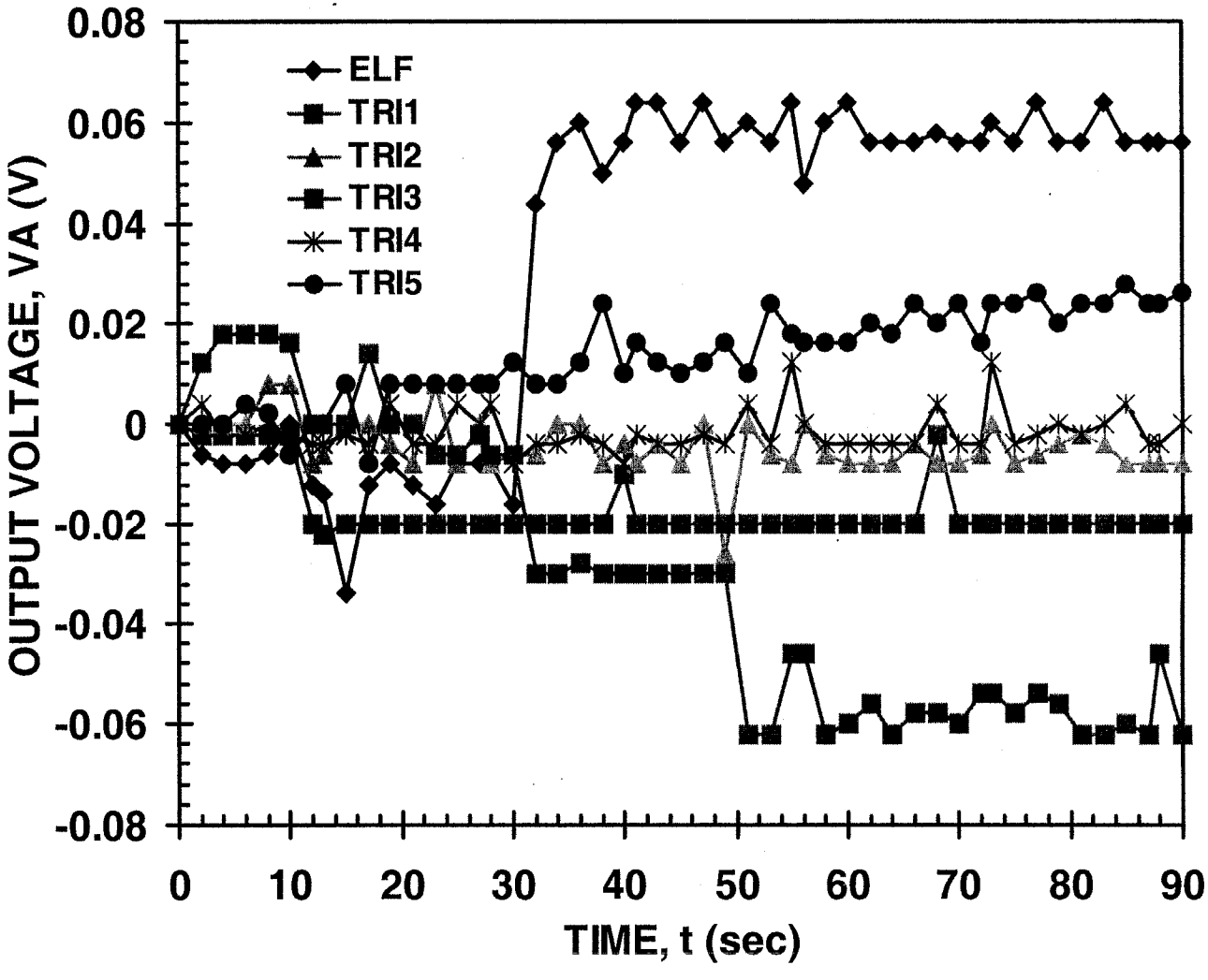
Triboelectric Sensor Response: Particle Removal



TRI1 is ABS, TRI2 is polycarbonate, TRI3 is Teflon, TRI4 is Rulon-J, and TRI5 is Teflon which were rubbed with wool felt.

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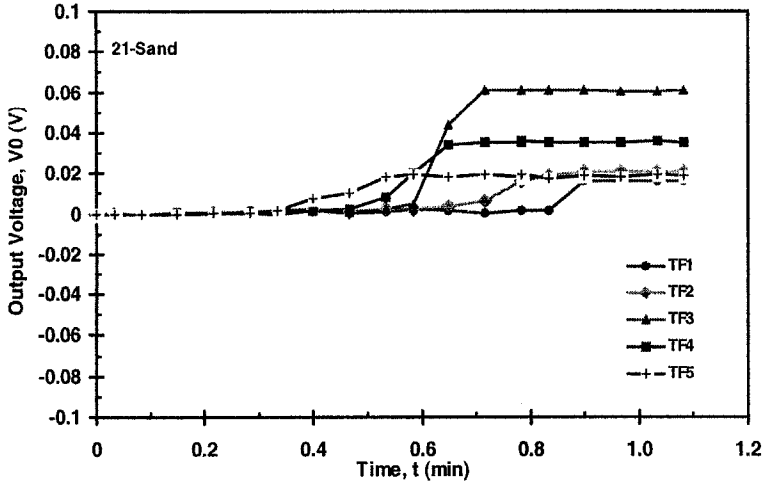
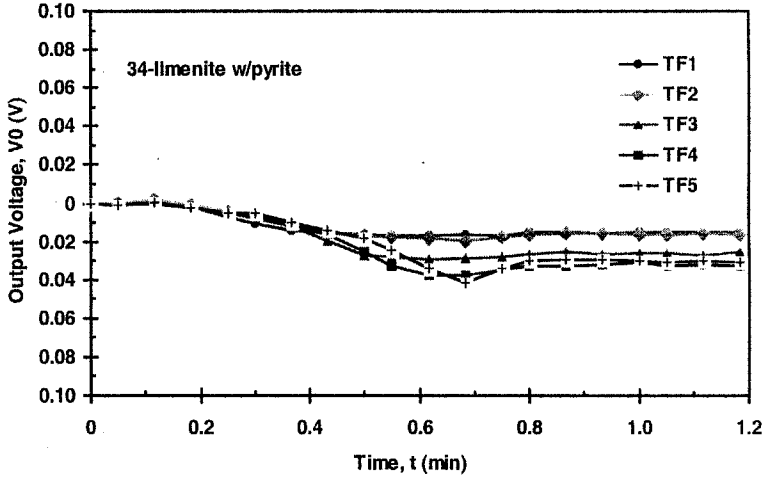
Triboelectric Sensor Response: Soil-Dust Exposure Test

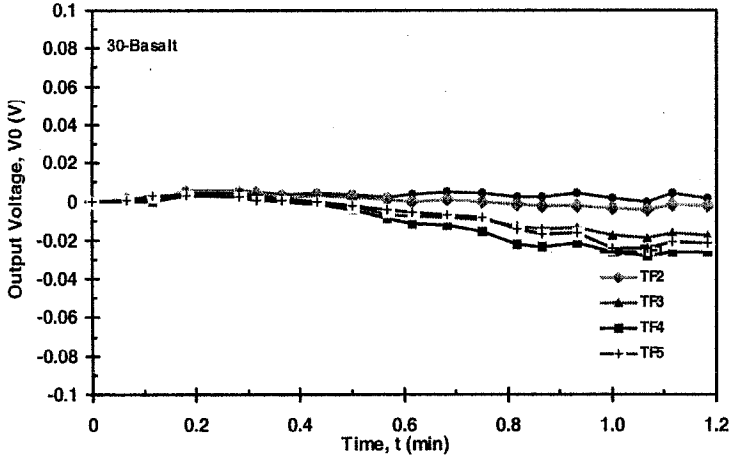
Sand



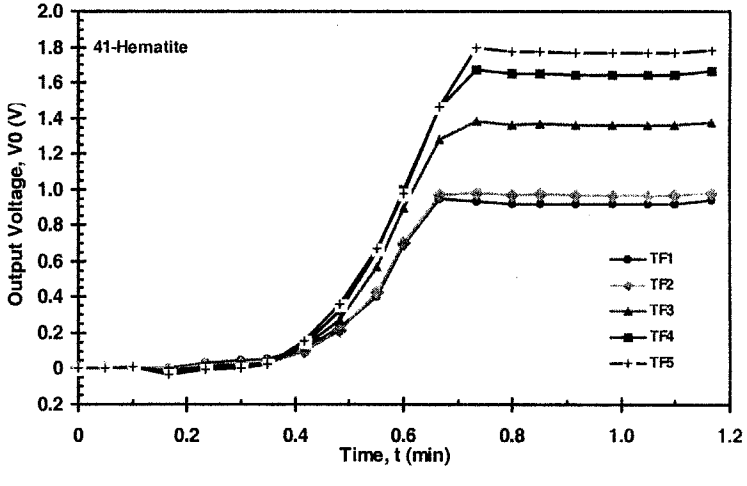
Ilmenite w/ pyrite



Basalt



Hematite Dust



No insulators placed over the triboelectric sensors.

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ELECTROMETER DEVELOPMENT CYCLE

PROTOTYPES (NO.)	START DATE	COMMENTS
ELE18614 (1)	14 Jun 1998	Switch leakage too high
ELE28B01 (1)	1 Nov 1998	Ion current chamber evaluation
ELE38B22 (1)	22 Nov 1998	Breakdown ~45, kV
ELE48B01 (2)	1 Dec 1998	More Breakdown studies Ion current studies
ELE58C27 (1)	27 Dec 1998	Soil-dust studies
ELE69131 (2)	31 Jan 1999	First insulators installed First triboelectric rubbing First serial interface
ELE79417 (1 maybe 2)	17 Apr 1999	First titantium housing First automatic rubbing
ELE89502 (8 in fab)	2 May 1999	Flight equipment Material selection (TBD) Martian Soil response (TBD)

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CONCLUSION: It takes the following to make it happen.

People Expertise:

- **Triboelectricity: Ray Gompf**
- **Electric fields: Otto Orient**
- **SPICE Circuit analysis: Le-Jen Cheng**
- **CAD Mechanical Design: Mike Thelen**
- **Board Layout: Martin Buehler**
- **Procurement: Li-Jen Cheng**
- **Systems: Terry Freeman, ASU**
- **Science Advisory Panel: twelve international members**
- **Management: Mike Hecht, Mitch Shellman and Lynne Cooper**

Parts Availability:

- **Rapid Turn Electronics Suppliers: (Digi-Key, Mouser)**
- **Specialty Electronics: (IMS...high value resistors)**
- **Mechanical parts: (Small Parts, Inc.... screws)**
- **Triboelectric Materials: (Small Parts, Inc, KSC)**

Fabrication:

- **Board Fabrication: T-Tech**
- **Precision Titanium Machining: Micro Steel**
- **Flight Class Assembly: Halcyon**

Testing:

- **Mars Simulators: JPL and KSC**
- **Flight Test (Burn-in, vibration, thermal cycle): JPL**